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Capital Mobility and the Scope for Sterilization: Mexico in the 1970s

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Robert E. Cumby and Maurice Obstfeld*

This paper studies the interaction between Mexico's capital account and domestic credit policy during the decade 1970-1980. It seeks in particular to measure the offset to monetary policy due to interest-sensitive capital flows, and, in doing so, is careful to account for the potential estimation bias introduced by central-bank sterilization activities. The empirical record suggests that the instantaneous capital-account offset to monetary policy, while substantial, was less than complete in the 1970s. The Banco de Mexico's short-run control of the monetary base allowed it to attempt the complete sterilization of foreign reserve movements, at least over part of the decade.

Empirical studies of offsetting capital flows have concentrated almost exclusively on the industrialized, North Atlantic economies.[1] But the impact of capital mobility on domestic monetary management is of great importance for Mexico, which has long allowed relatively unrestricted external asset trading, and for other industrializing economies (such as Chile) which have recently removed impediments to capital-account transactions. Mexican authorities fear that reserve inflows associated with increasing oil exports will place upward pressure on domestic prices and

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lead to an overvalued exchange-rate and the elimination of traditional export sectors (see Ortiz and Solís (1979)); sterilization, if feasible, could reduce these inflationary pressures in the short-run. Similarly, Argentina experienced substantial capital inflows and real exchange-rate appreciation as a result of the disinflation policy it pursued in the late 1970s. Sterilization might mitigate these problems during the transition to lower inflation rates in countries (such as Uruguay) following strategies similar to Argentina's.

Broadly speaking, the econometric approaches taken in the industrialized-country studies of the capital-account offset may be classified either as "reduced-form" (Porter (1972), Kouri and Porter (1974), Girton and Roper (1977)) or "structural" (Herring and Marston (1977), Obstfeld (1980a)).[2] In this paper, we apply the structural approach to the recent Mexican evidence. This strategy avoids the simultaneous-equations bias that may distort reduced-form offset estimates in the presence of a sterilization rule.

An additional feature of our econometric technique deserves mention. Along with the standard two-stage least squares estimates of the Mexican structural equations, we present estimates based on the two-step two-stage least squares procedure proposed by Cumby, Huizinga, and Obstfeld (1981). The theoretical advantages of the latter estimator are discussed in context below.

The plan of the paper is as follows.

Section I distinguishes between offsetting capital movements and systematic sterilization as possible causes of an empirical negative correlation between capital inflows and increases in the domestic source

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component of the monetary base. We briefly review the reduced-form approach to the offset in the light of possible feedback from the balance of payments to the central bank's domestic assets.

Section II describes our empirical measure of domestic credit expansion, and estimates a quarterly Banco de Mexico reaction function relating changes in the domestic source component of the high-powered money stock to the balance of payments and the government's borrowing requirement. We find that reserve flows were a significant determinant of domestic credit movements in the 1970s, and are unable to reject the hypothesis that sterilization of reserve flows was complete, at least over the second half of the decade.

Section III estimates the parameters of a small, aggregative model of Mexico's money market and capital account. The underlying portfolio-balance model of the capital account assumes that peso-denominated non-money assets and covered foreign assets are imperfect substitutes in portfolios, and allows for the gradual adjustment of portfolio shares to their desired values. The empirical results imply that, depending on how the increase in the money supply was effected, anywhere between 30 and 50 per cent of an expansion in domestic credit was offset by capital outflow in the same quarter. The offset would have been higher had asset markets adjusted fully within one quarter.

Section IV briefly discusses the extent to which a systematic relationship between domestic credit movements and the futures premium on foreign exchange might alter the results of Section III. The data reveal a pronounced relation between the futures premium and lagged deviations from purchasing-power parity. We argue that expectations concerning possible peso devaluation were the major determinant of the premium.[3]

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Section V contains some concluding remarks. An appendix describes the construction of the data series employed in this study.

I. Sterilization and the Capital-Account Offset

When the exchange rate is pegged and international capital movements are sensitive to interest-rate differentials between countries, the capital-account response to domestic monetary measures diminishes their effect on the monetary base. An expansion of domestic credit, say, exerts downward pressure on domestic borrowing costs, inducing a reduction in net foreign indebtedness and a central-bank reserve loss that offsets some fraction of the intended increase in the base. When domestic and foreign securities are perfectly substitutable and portfolios adjust instantaneously, this offset is complete and immediate: the central bank possesses no control over the domestic money stock.[4]

Both imperfect substitutability between interest-bearing assets of different currency denomination and imperfect mobility of capital between financial centers may afford a central bank some short-run monetary independence. Neither necessarily enables the central bank to peg the price level or money supply indefinitely (see Obstfeld (1980b)). Imperfect substitutability can arise, for example, if various risks render stochastic the perceived return on domestic assets. When this is so, the desired portfolio share of domestic bonds in domestic wealth is an increasing function of the home interest rate, and the central bank can influence this interest rate (and so, the demand for money) by varying the stock of outside domestic currency debt available to private wealth owners.[5] Costs associated with rapid portfolio adjustment may allow

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international interest-rate arbitrage to occur only over time. Thus, imperfect capital mobility affords the monetary authority an independent means of temporarily influencing domestic credit conditions. The model of Mexico estimated below allows for both possible sources of short-run interest-rate independence in the presence of international asset trade.

The offset to monetary policy gives rise, empirically, to a negative correlation between the capital-account surplus and increases in the domestic component of the base. Figure 1 plots the change in Banco de Mexico's reserves against the seasonally-adjusted change in domestic credit, and is suggestive of such a negative correlation in the Mexican case.[6] But the absolute magnitude of this correlation, by itself, is not evidence of a powerful capital-account offset. Central banks frequently take advantage of any short-run monetary control they possess to sterilize reserve flows. Their attempts to divorce the balance of payments from the high-powered money supply introduce an additional source of systematic negative correlation between domestic credit expansion and capital inflows. A sterilization rule increases reserve volatility, but can successfully counteract balance-of-payments influences on the money supply in the short run when the capital-account offset is incomplete. Under sterilization, there is a systematic contemporaneous feedback from the balance of payments to the domestic assets of the central bank. These two variables are jointly, endogenously determined by the preferences or private asset holders and the monetary policy reaction function of the central bank.

Attempts to measure the offset coefficient -- the fraction of any domestic credit increase offset by capital outflow over the relevant time horizon -- have often failed to account for sterilization, and instead

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view the domestic source component of the base as a predetermined variable for purposes of estimation. Studies adopting this assumption produce estimates of the offset which reflect the central bank's policy as well as the true capital-account response to domestic credit expansion, but they erroneously ascribe the computed correlation exclusively to the latter. This is true in particular of the "reduced-form" approaches to the offset coefficient, which use ordinary least squares to regress the capital-account surplus on the contemporaneous increase in domestic credit, the current account surplus, and the exogenous determinants of changes in the external asset position and the domestic interest rate (usually the contemporaneous change in the foreign interest rate and home income).[7] When the monetary authority pursues a sterilization policy, the resulting least-squares estimate of the domestic credit variable's coefficient is not a consistent estimate of the offset coefficient, for this variable is correlated with the capital-flow equation's disturbance term. The bias this correlation imparts to the estimated offset is discussed by a number of authors, including Magee (1976), Girton and Roper(1977), Murray(1979) and Obstfeld (1980a).

In the next section we estimate a Banco de Mexico monetary policy reaction function. The results provide strong evidence that the Mexican authorities pursued a systematic policy of full sterilization during at least the second half of the 1970s. To avoid the bias this might introduce into "reduced-form" results, we then estimate a small structural model of Mexico's financial markets. This allows us to calculate estimates of the offset coefficient by tracing the effect on the stock of net external claims of increases in the monetary base. The structural model allows for gradual

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asset-market adjustment, and thus allows us to distinguish empirically between the consequences of imperfect substitutability and imperfect mobility of capital. Accordingly, we report estimates of both the short-run or one-quarter offset coefficient, and the long-run offset coefficient. The former gives the fraction of a monetary expansion reversed by capital outflow in the same quarter on the assumption that output and the price level are predetermined; the latter is a hypothetical construct measuring what the short-run offset would be if asset holdings could adjust immediately to their long-run desired levels.

II. The Banco de Mexico's Reaction Function

In this section we examine the extent to which the Banco de Mexico systematically neutralized the monetary effects of its foreign-exchange intervention. To begin, we describe the construction of a domestic credit policy variable which summarizes the effects of a variety of instruments available to the central bank. We next estimate a central-bank reaction function relating the level of this policy variable to a number of macroeconomic variables. The central finding is that a policy of systematic sterilization appears to have been followed at least during the second half of the 1970s. Not surprisingly, we find also that credit policy is influenced strongly by the need to finance the government's deficit, and that seasonal variation in liquidity preference is accommodated by the monetary authority.

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To construct a comprehensive measure of monetary policy suited to the recent Mexican experience, two important adjustments of the published domestic credit series are required. The first involves the treatment of decisions to monetize changes in the peso value of the Banco de Mexico's international reserves. The second incorporates the effects of variations in the reserve requirements imposed on private banks.

The peso value of the Banco de Mexico's foreign reserves may change for two reasons other than actual foreign-exchange intervention. The first of these is fluctuations in the market price of gold. Since the second quarter of 1976, the Banco de Mexico has revalued its gold holdings daily to reflect prevailing market prices. As a result, the dollar value of gold holdings increased by more than 500 per cent between 1975 and 1979, while physical gold holdings declined by 45 per cent over the same period.[8] A second source of reserve change in the absence of balance-of-payments disequilibrium is exchange-rate variation. When the peso-dollar rate was altered abruptly in 1976, Banco de Mexico experienced a substantial capital gain, in peso terms, on its holdings of foreign-currency denominated assets. Devaluation, like the gold-price increases, inflates the book value of reserves.

The decision to monetize such capital gains as a means of government finance is entirely discretionary. The alternative is the creation of a fictitious accounting liability that offsets the increase in the peso value of central-bank foreign assets without directly increasing the high-powered money stock. Monetization is thus completely analogous to an increase in the domestic assets of the central bank, even though it presupposes a rise in the peso value of the banks's foreign assets, It should be included in any measure of domestic credit change and excluded when calculating foreign

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reserve changes.[9]

Minimum reserve requirements for private banks were varied several times during the 1970s, and these changes, too, should enter into a summary measure of domestic credit policy. We incorporate them by assuming that policy makers think in terms of an adjusted monetary base, that is, a base adjusted to reflect the effect of average reserve ratio changes on the volume of demand deposits it supports. (We abstract from currency in circulation.) The adjusted base at time t, BA_t, is given by

$$BA_t = \frac{q_o}{q_t} B_t,$$

where q_o is the base-period average reserve ratio, q_t the current reserve ratio, and B_t the unadjusted base, measured in pesos.[10] BA_t is just the base that would support a money supply equal to B_t/q_t were the average reserve ratio at its base level q_o.

Letting $\Delta FACB_t$ denote the change in central-bank foreign assets over period t (excluding valuation changes) and $\Delta DACB_t$ the change in central-bank domestic assets over period t (including monetized capital gains on foreign reserves), we may write

$$BA_t = BA_{t-1} + \frac{q_o}{q_{t-1}} [\Delta FACB_t + \Delta DACB_t + \Delta B_t^*], \qquad (1)$$

where $\Delta B_t^* = [(q_{t-1} - q_t)/q_t] B_t$. Because

$$(B_t + \Delta B_t^*)/q_{t-1} = B_t/q_t ,$$

ΔB_t^* is the increase in the unadjusted base that would, at reserve ratio q_{t-1}, bring about the same rise in the volume of demand deposits supported

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by B_t as a reduction of the reserve ratio from q_{t-1} to q_t. The quantity $(q_o/q_{t-1})\ \Delta B_t^*$ appearing on the right-hand side of (1) thus measures the impact of the reserve ratio change on the adjusted base.

Identity (1) suggests a natural measure of overall domestic credit policy:

$$\Delta MP_t = \frac{q_o}{q_{t-1}}\ \Delta DACB_t + \frac{q_o}{q_{t-1}}\ \Delta B_t^* . \qquad (2)$$

We take ΔMP to be the dependent variable in the Banco de Mexico's monetary reaction function, and turn next to a discussion of the appropriate independent variables.

A central-bank reaction function should allow for response to a number of factors in addition to the balance of payments. Monetary policy, as defined by (2), may respond also to real output fluctuations, to changes in Mexico's international competitiveness as measured by the real exchange rate, and to seasonal fluctuations in money demand. Further, in the Mexican case, the government's borrowing requirement is a major factor influencing domestic credit creation. We therefore specified a reaction function of the form:

$$\Delta MP_t = a_o + a_1\ (q_o/q_{t-1})\,\Delta FACB_t + a_2(q_o/q_{t-1})\,GOVBOR_t + a_3 P_{t-1}$$
$$+ a_4 \ell n(y_{t-1}/y_{t-2}) + \sum_{i=1}^{3} a_{4+i} Di + u_{1t} . \qquad (3)$$

In (3), GOVBOR is the government deficit, $p \equiv \ell n(ePUS/PMex)$ the log of the real exchange rate, y the index of real industrial production, and Di a seasonal dummy for the i^{th} quarter. PUS and PMex are the U.S. and Mexican price levels, while e is the peso price of U.S. dollars.[11]

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When the central bank pursues a systematic sterilization policy, a_1 is negative. If $a_1 = -1$, the monetary authority seeks to neutralize all reserve flows through offsetting movements in domestic credit: sterilization is complete. A positive value of a_1 indicates that monetary policy is aimed at external balance.

The role of government deficit finance is particularly important in Mexico.[12] In general, that part of the government deficit not financed through external borrowing must be financed through the domestic banking system. (The Banco de Mexico, since 1955, has induced private banks to hold a large portion of the central government's debt by allowing certain debt holdings to serve as required reserves.)

Thus, we expect the coefficient a_2 in (3) to be positive and close to 1, reflecting the importance of the banking system in financing the deficit. Because public external borrowing also plays an important role in financing the government deficit, we expect a_2 to be less than 1.

If the monetary authority adopts a competitiveness target, the coefficient a_3 of the lagged real exchange rate should be positive. Thus, when domestic prices rise more quickly than exchange-rate adjusted foreign prices, credit policy becomes more restrictive. If monetary policy is used to lean against cyclical activity fluctuations, a_4 is negative.

Finally, as the major seasonal influence on money demand is the fourth-quarter increase, the coefficients of the seasonal dummies should be negative.

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The results of estimating the reaction function appear in Table 1. The endogeneity of the balance of payments makes necessary an instrumental-variables estimation technique, and two different ones were employed. The first of these was Fair's (1970) version of two-stage least squares (2SLS), which incorporates a correction for first-order serial dependence in the equation's disturbance. The second was the two-step two-stage least-squares (2S2SLS) procedure proposed by Cumby, Huizinga, and Obstfeld (1981). An advantage of 2S2SLS is that the asympotic distribution theory it uses to calculate parameter estimates' standard errors is valid under assumptions less restrictive than those adopted by Fair.[13] But both estimation methods should yield consistent parameter estimates in the present case.

Initially, the specification (3) was used; the results are reported as equations (A) and (C) in Table 1. Both estimates give the competitiveness term the expected positive sign, but they provide no evidence that counter-cyclical considerations influence domestic credit policy. Equations (B) and (D) present estimates of a reaction function from which the statistically insignificant competitiveness and cyclical variables have been excluded. The remaining coefficients exhibited relatively little sensitivity to this exclusion restriction.

The accommodation of seasonal money-demand shifts is apparent in all the estimates, with a strong seasonal expansion in the fourth quarter.[14] The government borrowing requirement is highly significant in all the regressions, indicating that roughly 70 to 80 per cent of the deficit is financed through domestic credit creation.

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Table 1. Mexico: Reaction Function (1971:3 to 1979:4)1/

Method	Constant	$(q_o/q_{-1})\Delta$FACB	(q_o/q_{t-1})GOVBOR	p_{-1}	$\ell n\,(y_{-1}/y_{-2})$	D1	D2	D3	$\hat{\rho}$	SE	R^2
A) Fair	20.8	-1.266	0.760	22.7	67.7	-40.0	-18.1	-41.2	-0.82	10.6	0.747
	(10.9)	(0.595)	(0.172)	(22.4)	(73.6)	(20.7)	(5.0)	(21.5)	(0.13)		
B) Fair	16.8	-1.453	0.834			-32.9	-17.1	-31.6	-0.73	10.6	0.729
	(7.8)	(0.655)	(0.181)			(14.2)	(4.5)	(14.2)	(0.17)		
C) 2S2SLS 2/	21.2	-1.153	0.691	21.3	39.7	-40.3	-17.0	-38.2	-0.86	9.4	0.738
	(25.5)	(0.223)	(0.121)	(13.0)	(51.9)	(50.8)	(3.4)	(48.3)	(0.26)		
D) 2S2SLS	13.0	-1.315	0.737			-25.4	-14.8	-21.8	-0.69	9.7	0.721
	(3.1)	(0.127)	(0.102)			(4.6)	(2.6)	(3.7)	(0.09)		

1/ Standard errors are in parentheses. Mean of dependent variable is 5.8 billion Mexican pesos. Instruments used were a constant, three seasonal dummies, lagged monetary policy, lagged reserve changes, lagged government deficit, once and twice lagged competitiveness and real income changes, foreign income and the foreign interest rate. When the lagged competitiveness and cyclical terms were dropped in (B) and (D), these variables were also removed from the instrument list. This choice of instruments allows the government deficit to be endogenously determined.

2/ Equation (C) reports two-stage least-squares estimates that use a heteroskedasticity-consistent estimate of the parameter estimates' variance-covariance matrix. These results, rather than the more efficient second-step estimates, are reported here because the algorithm for computing the latter failed to converge after 200 iterations. The parameter estimates obtained after 200 iterations were virtually identical to those reported in (C), however. For example, the sterilization coefficient was -1.158 and the government deficit's coefficient was 0.692.

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Most importantly, the balance-of-payments coefficient $\hat{a}_1$ is negative and has a marginal significance level exceeding 95 per cent in all versions of the reaction function. Although $\hat{a}_1$ is always smaller than -1, it is more than one standard error away from -1 only in equation (D). Thus, one cannot strongly reject the hypothesis $a_1=-1$. The data suggest that the Banco de Mexico attempted to control the money stock through full neutralization of reserve flows.

To investigate the stability of the reaction function, we split our sample into two sub-periods, 1971:3 - 1975:4 and 1976:1 - 1979:4. In the first sub-period there appeared to be no significant relationship between domestic credit policy and any of the explanatory variables (other than dummies). The relationships estimated over the second sub-period were similar to those reported in Table 1:

$$\text{(Fair)}\quad \underset{}{\Delta MP} = \underset{(42.9)}{58.0} - \underset{(0.733)}{1.525}\left(\frac{q_o}{q_{-1}}\right)\Delta FACB + \underset{(.435)}{.646}\left(\frac{q_o}{q_{-1}}\right) GOVBOR - \underset{(82.8)}{104.4}\, D1$$

$$\underset{(9.8)}{-30.0}\, D2 - \underset{(81.3)}{99.7}\, D3$$

$$\hat{\rho} = \underset{(0.09)}{-0.92} \qquad SE = 13.0 \qquad R^2 = 0.838$$

$$\text{(2S2SLS)}\quad \underset{}{\Delta MP} = \underset{(128.2)}{49.9} - \underset{(0.218)}{1.425}\left(\frac{q_o}{q_{-1}}\right)\Delta FACB + \underset{(0.209)}{0.506}\left(\frac{q_o}{q_{-1}}\right) GOVBOR - \underset{(260.0)}{87.0}\, D1$$

$$\underset{(3.7)}{-28.3}\, D2 - \underset{(256.0)}{80.3}\, D3$$

$$\hat{\rho} = \underset{(0.45)}{-0.90} \qquad SE = 10.1 \qquad R^2 = 0.842\ .$$

These results suggest that sterilization was a more important factor in monetary policy during the second half of the 1970s than during the first half.[15] The finding is consistent with the fact that the range of monetary tools available to the Banco de Mexico broadened considerably after 1975.[16]

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We conclude that part of the observed negative correlation between changes in the domestic and foreign source components of the base is likely to be due to official sterilization policy. An implication is that domestic credit policy responds to the balance of payments, and should not be treated as an exogenous factor in estimating the capital-account offset coefficient.

III. A Structural Model of Asset Markets

In this section we estimate a small, aggregative portfolio-balance model of Mexican financial markets. The model allows the calculation of both the short-run and long-run offset coefficients. It consists of three equations, a demand equation for the net external liabilities of the Mexican private sector, a money demand equation, and a money supply equation. All equations were estimated by two-stage least squares (with Fair's autoregressive correction when necessary) and by the 2S2SLS procedure. A list of the instruments used is provided in a note to Table 2.

Both the money and external liability demand equations relate desired asset holdings to the expected return on foreign assets. An important component of this return is the expected depreciation of the peso relative to foreign currency. The presence of a large, discrete devaluation of the peso in 1976:3 poses a problem, for it is unlikely that the devaluation was completely unanticipated, or that anticipations of exchange rate movements were a minor determinant of capital flows in 1976-77. Indeed, Figure 1 presents striking evidence that the devaluation of 1976 was preceded by a sizable anticipatory outflow of capital.

To capture the impact of exchange rate expectations, we used the premium on three-month peso futures as an explanatory variable in our empirical equations.[17] This premium does reflect the anticipation of a

devaluation for several quarters preceding 1976:3, but was always substantially smaller than the realized devaluation.

Each equation is now discussed in turn. At the end of the section, the implied offset coefficients are calculated.

1. Net foreign liabilities

We assume that the real peso value of the desired stock of net external liabilities, $eF^d/PMex$, may be written as a function of domestic and foreign interest rates, domestic real income, and domestic real wealth:

$$\frac{eF^d}{PMex} = \phi(r,\ r^* + f,\ y,\ W/PMex) + u_2. \qquad (4)$$

In (4), r is the domestic interest rate, r* the foreign rate, f the premium on peso futures, and W nominal Mexican wealth.[18] We assume that Mexican participants comprise a sufficiently small share of the world financial market that the foreign interest rate may be taken as exogenous. In addition, we assume that foreign holdings of peso-denominated assets are negligible, so that we may ignore the effects of foreign income and wealth. To incorporate the possibility of imperfect capital mobility, we suppose that agents need not adjust portfolio shares instanteneously to their full optimum level, but instead succeed in making a fraction λ of the adjustment each period. Thus,

$$eF/PMex - e_{-1}F_{-1}/PMex_{-1} = \lambda(eF^d/PMex - e_{-1}\ F_{-1}/PMex_{-1}), \qquad (5)$$

where F is the actual stock of net foreign liabilities, measured in dollars.

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Combining equations (4) and (5) and linearizing, we obtain the equation to be estimated,

$$\frac{e_t F_t}{PMex_t} = b_o + b_1 \frac{e_{t-1}F_{t-1}}{PMex_{t-1}} + b_2 r_t + b_3(r_t^* + f_t) + b_4 y_t + b_5 W_t/PMex_t + \varepsilon_{2t}, \quad (6)$$

where $b_1 = 1 - \lambda$ and $\varepsilon_{2t} = \lambda u_{2t}$. A rise in the home interest rate induces an inflow of capital or an increase in net external liabilities, so $b_2 > 0$. Similarly, $b_3 < 0$. An increase in domestic real income augments the transactions demand for money and causes a decline in desired holdings of foreign assets, so $b_4 > 0$. Finally, an increase in domestic wealth leads to a reduction in external liabilities. Thus, $b_5 < 0$.

The results of estimating (6) are reported in Table 2.[19] They provide evidence that capital flows are quite sensitive to the domestic interest rate even in the short run. The two techniques yield very similar parameter estimates, although those obtained by 2S2S2S appear to be more precise. All interest rate coefficients have the expected sign and are significant at the 95 per cent level. Equation (B), for example, suggests that a 100 basis point rise in the home interest rate, all else equal, induces a capital inflow of 1.2 billion real pesos in the same quarter, while an equal increase in the covered foreign rate induces a 0.25 billion real peso outflow. Both estimates of the adjustment parameter are near 0.7. Again using equation (B), the long-run capital inflow occasioned by a 100 basis point rise in r is 3.9 billion real pesos, while the outflow following an equal increase in $r^* + f$ is 0.83 billion real pesos.

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Table 2. Mexico: Net Foreign Liabilities (1971:3 - 1979:4)1/

Method	Constant	r	r* + f	W/PMex	$\frac{e_{-1}F_{-1}}{PM_{ex-1}}$	$\hat{\rho}$	SE	R^2
(A) Fair	4.64	1.46	-0.265	-0.207	0.605	-0.46	3.263	0.935
	(3.14)	(0.29)	(0.103)	(0.064)	(0.073)	(0.158)		
(B) 2S2SLS	3.22	1.161	-0.252	-0.150	0.696	-0.866	3.425	0.916
	(1.08)	(0.146)	(0.066)	(0.032)	(0.025)	(0.131)		

1/ Standard errors are in parentheses. Mean of dependent variable is 6.73 billion 1975 Mexican pesos. As in the regressions reported in Tables 3 and 4, the instruments used here are a constant, three seasonal dummies, the contemporaneous foreign interest rate and real income level, the lagged government deficit, lagged domestic real income, the lagged futures premium and the lagged dependent variable. This choice of instruments allows the domestic interest rate, futures premium, real income and budget deficit to be endogenous. The use of contemporaneous foreign variables as exogenous instruments is justified if Mexico can be regarded as a small country in world markets for goods and assets. When necessary, the instrument list was augmented to satisfy Fair's minimum criterion.

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The wealth variable has the anticipated sign and is significant at the 95 per cent level in both equations. Equation (B) suggests that approximately 15 per cent of an increase in wealth is allocated to net external assets within one quarter. The long-run portfolio share is 50 per cent.

2. Money demand

The demand for narrowly-defined real money (M1) balances is assumed to depend on the domestic and foreign covered interest rates, real income, and real wealth. Thus, long-run desired money holdings may be written as

$$\frac{M^d}{PMex} = \Lambda(r,\ r^* + f,\ y,\ W/PMex) + u_3.$$

Invoking the partial adjustment mechanism and linearizing as before, we obtain the empirical specification,

$$\frac{M_t}{PMex_t} = c_o + c_1 \frac{M_{t-1}}{PMex_{t-1}} + c_2\, r_t + c_3(r_t^* + f_t) + c_4 y_t + c_5 W_t/PMex_t + \varepsilon_{3t}, \qquad (7)$$

where $1 - c_1$ is again the adjustment parameter. As usual, we expect c_2, $c_3 < 0$, c_4, $c_5 > 0$.

The results of estimating (7) appear in Table 3.[20] As before, the two-stage least-squares (2SLS) and the 2S2SLS estimates are quite similar. Table 3 reports two versions of the money-demand equation. In (A) and (B) we estimate the money demand equation without imposing coefficient constraints while in (C) and (D), the two rate-of-return coefficients are constrained to be equal. In neither case is the constraint rejected by the data. When the constraint is imposed the coefficient on the interest

Table 3. Mexico: Money Demand (1971:3 to 1979:4)1/

	Method	Constant	r	r* + f	y	$\frac{M-1}{PMex-1}$	D1	D2	D3	S.E.	R^2
(A)	2SLS	5.877	-0.560	-0.324	0.426	0.828	-28.7	-21.3	-22.1	4.04	0.962
		(6.100)	(1.002)	(0.170)	(0.193)	(0.228)	(5.0)	(2.6)	(2.2)		
(B)	2S2SLS	5.498	-0.723	-0.347	0.446	0.838	-29.5	-21.7	-22.0	3.65	0.961
		(3.279)	(0.952)	(0.121)	(0.050)	(0.134)	(2.8)	(1.6)	(1.8)		
(C)	2SLS	6.201	-0.312	-0.312	0.418	0.801	-28.1	-20.9	-21.9	3.86	0.964
		(5.689)	(0.156)	(--)	(0.182)	(0.192)	(4.0)	(2.1)	(1.9)		
(D)	2S2SLS	6.464	-0.306	-0.306	0.440	0.782	-28.5	-21.4	-22.0	3.47	0.965
		(2.383)	(0.086)	(--)	(0.056)	(0.050)	(1.9)	(1.5)	(1.7)		

1/ Standard errors are in parentheses. Mean of dependent variable is 104.8 billion 1975 Mexican pesos. See footnote in Table 2 for instruments.

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rates is significant at the 95 per cent level. In the unconstrained equation only the coefficient on the foreign interest rate is significant.

The adjustment of real balances to long-run desired levels is estimated to be approximately 20 per cent per quarter. Equation (D), for example, suggests that a 100 basis point increase in either rate of return leads to a 0.3 billion peso decrease in real money demand in the same quarter and a 1.4 billion peso decrease in real money demand in the long run.

As expected, an increase in real income raises real money demand. At the sample means of y and M/PMex, the income elasticity of money demand derived from equation (D) is 0.42 in the short run and 1.94 in the long run. The empirical equation also contains seasonal dummies, which reveal a marked seasonality in money demand. It is this seasonal variation that gives rise to the significant seasonal dummies in the Banco de Mexico's domestic credit policy function.

3. Money supply

The model's monetary sector includes a money supply function relating the supply of real M1 to the real monetary base. We assume that the supply of money by the private banking system may be written as a function of the monetary base (adjusted for reserve requirements as described in Section II) and of the opportunity cost of holding excess reserves. When linearized, the money supply function takes the form,

$$\frac{M^S_t}{PMex_t} = d_o + d_1 r_t + d_2 \frac{BA_t}{PMex_t} + u_{4t}. \qquad (8)$$

Estimates of the parameters of (8) are reported in Table 4.[21] The coefficient of the real, adjusted base is quite small, reflecting both

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Table 4. Mexico: Money Supply (1971:3 - 1979:4)1/

Method	Constant	r	BA/PMex	$\hat{\rho}$	SE	R^2
(A) Fair	10.83	2.249	1.016	0.717	5.620	0.907
	(12.90)	(1.166)	(0.111)	(0.128)		
(B) 2S2SLS	2.7	2.392	1.042	0.829	5.558	0.909
	(11.0)	(0.943)	(0.054)	(0.101)		

1/ Standard errors are in parentheses. Mean of dependent variable is 104.8 billion 1975 pesos. See footnote in Table 2 for instruments.

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high marginal reserve requirements on demand deposits (in place throughout the estimation period) and banks' practice of holding sizable excess reserves.[22] The high interest sensitivity of money supply is also consistent with the existence of significant excess reserves.

4. The offset coefficient

The estimated coefficients of the structural equations may be used to calculate the capital-account offset to domestic credit expansion. Two types of monetary expansion are considered. The first is an increase in domestic credit accomplished through an open-market-type asset swap that leaves private financial wealth unchanged. The second is a helicopter-type increase in credit that is accompanied by an equal increase in private financial wealth. Because our empirical money-demand function does not include domestic wealth as an argument, we would expect the offset associated with the latter type of operation to be the greater one. Indeed, were b_5 equal to -1, the offset to a helicopter increase in domestic credit would be complete, even with limited asset substitutability.

In both cases the offset coefficient is (minus) the total derivative of net foreign liabilities with respect to an increase in DACB. Table 5(a) contains the short-run offset coefficients for both types of credit expansion, computed from the two sets of parameter estimates using the constrained money-demand equations. The short-run offset coefficients imply that, while substantial, the capital account offset to a monetary expansion was considerably less than complete. At the initial reserve ratio, anywhere from 30 to 50 per cent of an increase in domestic credit by the Banco de Mexico was offset by capital outflow within a quarter, with the exact figure depending on the method through which the domestic-credit increase was effected.

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Table 5. Mexico: Offset Coefficients 1/

Credit Expansion	Estimation Method: Fair	Estimation Method: 2S2SLS
(a) Short Run		
Open market type	0.37	0.31
Helicopter type	0.51	0.41
(b) Long Run		
Open market type	0.50	0.51
Helicopter type	0.76	0.75

1/ Offset coefficients are calculated at base period reserve requirements. The capital-account offset to an open market-type credit expansion is given by

$$(q_o/q_t)b_2d_2/((d_1-c_2) + (q_o/q_t)b_2d_2). \quad (9)$$

The offset coefficient for the helicopter-type expansion is

$$\frac{(q_0/q_t)b_2d_2 + b_5(c_2 - d_1)}{(q_0/q_t)b_2d_2 + (d_1 - c_2)}. \quad (10)$$

For example, in order to achieve a 1 billion peso increase in the monetary base through outside money creation, a 1.7 to 2 billion peso expansion of domestic credit was required. As expected, the computed offsets to a helicopter-type expansion exceed those to an open-market type expansion, in both cases by approximately 10 percentage points. The offset coefficients derived from the Fair's method estimates exceed those derived from the 2S2SLS estimates. This difference is due to the greater domestic-interest-rate sensitivity of capital flows implied by the former set of estimates.

It is also of interest to calculate the offset in a hypothetical world in which portfolio adjustment occurs instanteneously. Replacing the parameters in (9) and (10) with their corresponding long-run values, we obtain "long-run" offset coefficients in all cases between 50 and 76 per cent (see Table 5(b)). The computed "long-run"offsets to open-market-type expansions are in the lower end of this range and those corresponding to helicopter-type expansions are near 76 per cent. It should be stressed that we are using the term "long run" in a limited sense to signify only the complete adjustment of asset stocks to their desired values.

The estimates indicate that the Banco de Mexico could exercise considerable short-run control over the domestic money stock and domestic credit-market conditions during the 1970s, but only at the cost of high reserve volatility.

IV. Expectations and the Futures Premium

The preceding anlysis, while recognizing the role of the futures price as an indicator of exchange-rate expectations, has neglected both the possible influence of the home interest rate on the futures premium and the endogeneity of expectations. The offset to monetary policy has

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been calculated on the assumption that a one-time expansion of domestic credit leaves the futures premium unchanged.

How might monetary expansion affect the futures premium? By lowering the domestic interest rate, monetary expansion would induce capital outflows and, at the initial forward rate, an excess demand for future pesos calling for a rise in their equilibrium price. As an appreciation of the peso on the futures market discourages capital outflow, the offset coefficient would be lower than calculated in the previous section if covered interest arbitrage were incorporated into the model.

Speculative transactions are also an important determinant of the futures price however, and the activities of the speculators would tend to raise the offset coefficient calculated in Section III. Monetary expansion raises the likelihood of devaluation by reducing the central bank's international reserves and encouraging domestic expenditure. Speculators would respond by selling the peso forward, thus enhancing the profitability of capital outflows.

Theoretically, the net effect on the futures prices of these two types of activity--interest arbitrage and speculation--is indeterminate. But as an empirical matter, we could find no strong evidence that contemporaneous domestic interest rates affected the futures premium during the 1970s. Expectations regarding the future level of the exchange rate did seem to be an important determinant of the futures premium, however. In particular, lagged deviations from purchasing power parity exerted a persistent and strong effect on the futures premium, with lagged real exchange-rate appreciation leading to forward depreciation of the peso.

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Letting $p \equiv \ln(ePUS/PMex)$ again denote the natural logarithm of the real exchange rate, we estimated the following relationhip between the futures premium on dollars, f, and past values of the real exchange rate between 1974:1 and 1979:4:

$$f_t = \underset{(3.669)}{13.998} - \underset{(7.344)}{42.605}\, p_{t-1} - \underset{(10.020)}{33.970}\, p_{t-2} - \underset{(10.681)}{28.013}\, p_{t-3}$$

$$- \underset{(9.987)}{10.923}\, p_{t-4} - \underset{(7.321)}{21.449}\, p_{t-5}$$

$$\hat{\rho} = \underset{(0.106)}{0.801} \qquad SE = 3.497 \qquad R^2 = 0.734$$

(standard errors are in parentheses). The correlations between the futures premium and lagged values of the purchasing power parity gap are extremely high. They suggest that any decline in the competitiveness of Mexican exports occasioned forward speculation against the peso and a rise in the premium on forward dollars.[23]

This strong evidence that expectational factors influenced the forward premium indicates that our offset estimates probably understate the true offset.

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V. Conclusion

This paper has studied the capital-account offset to monetary policy faced by the Banco de Mexico during the decade 1970-1980. Using a small structural model of Mexican financial markets, we found that roughly 30 to 50 per cent of a domestic-credit increase leaked away through the capital account within a quarter, with the precise figure depending on the method of domestic-credit expansion adopted. This incomplete offset was due to imperfect mobility of capital as well as to imperfect substitutability between peso-denominated assets and assets denominated in foreign currencies. The offset coefficient would have been approximately 50 to 65 per cent higher under instantaneous portfolio adjustment.

These findings imply that the Mexican central bank possessed some degree of short-run control over the monetary base in spite of the fixity of the exchange rate. While short-run monetary control implies an ability to neutralize the liquidity effects of transitory reserve fluctuations, it does not imply an ability to resist the adjustments necessary to eliminate sustained disequilibria in the balance of payments. Conclusions as to the scope for long-run monetary control cannot be drawn from our partial-equilibrium financial-sector model, which neglects the current-account effects of international wealth flows and changes in home borrowing costs.

Estimates of a Banco de Mexico reaction function provided strong evidence of official sterilization activities during the 1970s. Although the reaction function exhibited some instability when estimated over sub-periods of the decade, the Banco de Mexico seems to have pursued a policy of full neutralization of reserve movements, at least since early

1976. The pursuit of sterilization under conditions of substantial capital-account sensitivity helped give rise to periods of considerable reserve volatility during the decade under study.

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APPENDIX

The following data were employed in this study:

B: High-powered money in billions of pesos. The series is the sum of currency and the reserve deposits of deposit banks in the Banco de Mexico, including securities held at the Banco de Mexico in fulfillment of reserve requirements. Source: Indicadores Economicos, various issues, for data from 1974:1 to 1979:4. From 1970:4 to 1973:4, currency in circulation is taken from Indicadores Economicos and bank reserves from Informe Anual.

BA: Adjusted stock of high powered money, equal to $(q_0/q_t)B_t$.

D_1, D_2, D_3: Seasonal dummies taking the value of one in the i^{th} quarter ($i = 1, 2, 3$) and zero in other quarters.

ΔDACB: Change in Central Bank domestic assets. Calculated as ΔB-ΔFACB. Included are monetized capital gains on international reserves.

e: End-of-period exchange rate, in pesos per dollar. Source: International Financial Statistics (IFS), line ae.

f: End-of-quarter premium on peso futures for delivery three months forward, at annual rate. The premium is set at zero prior to 1974:2. Source: International Money Market Yearbook, various issues.

F: Private Mexican net external liabilities, in billions of dollars, calculated as the cumulated STCF + LTCF.

ΔFACB: Change in reserves of the Banco de Mexico, excluding valuation changes. Calculated as $e_t \Delta R_t$.

GOVBOR: The deficit of the Mexican central government, in billions of pesos. Source: IFS, line 80.

LTCF: Surplus on long-term private capital account, excluding direct foreign investment, in billions of dollars. Source: Indicadores Economicos, various issues.

M: Narrowly-defined money M1, in billions of pesos. Source: Indicadores Economicos, and Informe Anual, various issues.

PMex: Mexican CPI, 1975 = 1.00. Source: IFS, line 64.

PUS: United States CPI, 1975 = 1.00. Source: IFS, line 64.

q: Weighted average reserve requirement. End-of-quarter stocks of various domestic and foreign liabilities of the Mexican financial system are used to weight the marginal reserve requirement for each type of deposit. When more than one reserve requirement is published for a given type of deposit (depending, e.g., on location ofthe issuing institution), some effort is made to choose the rate which is likely to apply to the majority of deposits in that category. In addition, the series is adjusted so that $q_t = q_{t-1}$ if no change is made in legislated reserve requirements. Source: Indicadores Economicos for 1972:4 - 1979:4; Informe Anual for 1970:4 - 1972:3.

r: Domestic interest rate. The rate chosen is the gross yield on financiera bonds for 1971:1 - 1973:4 and the gross yield on three-month certificates of deposit from 1974:1 - 1979:4. Source: Indicadores Economicos.

r*: Three-month London Eurodollar rate. Source: IFS, line 60d.

ΔR: Change in foreign exchange reserves of the Banco de Mexico, in billions of dollars. The reserve series is taken from the balance-of-payments data in Indicadores Economicos and is based on a constant valuation of gold.

STCF: Short-term private capital-account surplus, in billions of dollars. The series includes the errors and omissions in the balance of payments

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until 1977:1, when short-term capital flows and errors and omissions were first published separately. Source: Indicadores Economicos.

y: Mexican index of industral production. Source: IFS, line 66.

YUS: U.S. disposable income (nominal). Source IFS, line 99a.

W: Mexican financial wealth, calculated as $B_t + (-e_t F_t)$.

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Footnotes

[1]An exception is Miller and Askin (1976), which studies Brazil and Chile.

[2]The early paper of Argy and Kouri (1974) does not fall easily into either of these categories. See note 7, below, for further discussion.

[3]The peso was devalued on August 31, 1976.

[4]See Keynes (1930, vol. 2, p. 309) and Mundell (1963). A key assumption in deriving this result is that the central bank expands domestic credit through an open-market operation that leaves private wealth unchanged. If domestic credit instead represents outside money and the public's demand for money is a function of its wealth, the capital-account offset will not be complete, even under perfect capital mobility and unlimited asset substitutability. Below, we compute the empirical offset coefficients associated with both types of domestic credit creation.

[5]Even when foreign and home bonds are imperfect substitutes, the central bank may be unable to affect the monetary base if government debt is not outside debt; see Obstfeld (1981) and Stockman (1979). We ignore below the problems that can arise when the public internalizes the government and central-bank budget constraints.

[6]The series are adjusted for reserve requirements as described in the next section.

[7]The "reduced-form" capital flow equation, as estimated by Kouri and Porter (1974), is derived in two steps. First, one writes the change in net external lending over a quarter as a function of the change in the foreign and home interest rates and the change in income and other determinants of the capital account. Second, one eliminates the change in the domestic interest rate from this equation using the (first-differenced) money-market equilibrium condition, which relates the quarterly change in (base) money demand to the sum of the capital account, the current account, and the increase in central bank domestic assets. Equations that regress changes in reserves on changes in domestic credit, changes in income, and changes in the home interest rate (for example, Cardoso and Dornbusch (1980)), are clearly money-demand equations, and give no information regarding the effect of credit expansion on the capital account. (See Frenkel, Gylfason, and Helliwell (1980).) Balance-of-payments equations such as the one estimated by Connolly and Dantas da Silveira (1979), which are based on the assumption that money demand and the money supply multiplier are interest inelastic, assume implicitly that the capital-account offset to domestic credit expansion is complete. Indeed, when money supply and money demand are both interest inelastic, the Kouri-Porter capital-flow equation is under-identified. Identification is lost also when no variables other than the balance of payments enter the monetary policy reaction function. (This assumes that no a priori information is available concerning the degree of correlation between the disturbances of various equations.) If domestic credit responds systematically to variables other than the balance of payments, these variables, if predetermined, may be used as instruments in estimating the "reduced-form" capital-flow equation by two-stage least squares. This approach, which in principle yields consistent parameter estimates, was suggested by Argy and Kouri (1974). Their estimated offset coefficients were generally much smaller than those obtained using ordinary least squares.

[8]Calculations are based on year-end data published in International Financial Statistics, lines lad and land.

[9]The data appendix provides details on the construction of our central-bank domestic asset series

[10]Details on the calculation of the average reserve ratio series used in this study apear in the appendix.

[11]All variables are defined in detail in the appendix. Financial aggregates are measured in billions of pesos.

[12]We draw on the discussions of government deficit finance in Brothers and Solís (1966) and Ortiz and Solís (1979).

[13]The standard-error estimates produced by 2S2SLS allow for a non-zero covariance between the estimates of the structural parameters and the estimate of the autoregressive parameter (denoted by ρ in Table 1). In addition, 2S2SLS does not require the absence of conditional heteroskedasticity, an important problem is standard-error estimation when lagged endogenous variables are used as instruments. Conditional heteroskedasticity is discussed by Engle (1980) and Hansen (1979), and, in a cross-sectional context, by White (1980a, 1980b).

[14]This seasonality is reflected in the money-demand equation estimated below.

[15]Bhalla (1981) computes a positive correlation between the balance of payments and the change in the money stock using annual data for the period 1956-1972. This evidence also suggests that sterilization was of limited importance before the mid-seventies.

[16]Business International (1979) reports that Banco de Mexico has used Certificados de Tesoreria de la Federacion since 1978 and petrobonds since 1977 to conduct open-market operations. In addition, the move to market valuation of gold reserves in 1976 allowed greater flexibility in choosing the rate of domestic credit expansion. Prior to these innovations, the monetary authority relied on reserve-requirement changes, special deposits, and operations in government securities within the banking system (see Brothers and Solís). Only the last of these was employed with any frequency.

[17]The futures premium can be interpreted as an indicator of exchange-rate expectations or as the cost of forward cover. The two interpretations, of course, need not conflict. We use the futures premium rather than the forward premium used by Lizondo (this volume) because there is a longer series of observations available for the former variable. Jacob Frenkel has suggested that the futures premium may measure exchange-rate expectations with error. The two-step two-stage least squares estimates (but not the Fair's method estimates) reported below yield consistent parameter estimates even when all asset returns are measured with random, serially-uncorrelated error. See Cumby, Huizinga, and Obstfeld (1981) on the procedure to employ when an equation with errors in variables is corrected for autoregressive dependence of its structural disturbance.

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[18]We are assuming here that domestic and covered foreign bonds are imperfect substitutes because of political risk. See Aliber (1973) and Dooley and Isard (1980). One example of such political risk arises when the future tax treatment of international interest payments is uncertain.

[19]The domestic income variable had a small and very insignificant coefficient. It was therefore omitted from the equation reported in Table 2.

[20]Domestic wealth has been dropped from the equation, as its coefficient was small and insignificant. No evidence of serial correlation was found.

[21]There was no evidence of a lag in the adjustment of the money supply to its long-run level.

[22]Business International (1979) attributes this practice to the extremely limited recourse of commercial banks to rediscounting at the central bank. Generally, only certain export bills are discountable.

[23]The contemporaneous real exchange rate exerted no significant effect on the futures premium. This is probably the result of lags in the reporting of price-level figures.